PROCEEDINGS

OF THE

CALIFORNIA ACADEMY OF SCIENCES

FOURTH SERIES

SYSTEMATICS AND BIOLOGY OF THE DEEP-SEA FISH FAMILY GIBBERICHTHYIDAE, A SENIOR SYNONYM OF THE FAMILY KASIDOROIDAE[1]

By

Donald P. de Sylva

*University of Miami, Rosenstiel School of Marine and Atmospheric Science
Miami, Florida 33149*

and

William N. Eschmeyer

California Academy of Sciences, San Francisco, California 94118

ABSTRACT: The fish family Kasidoroidae Robins and de Sylva (1965) is shown to be based on Atlantic specimens of the unusual prejuvenile stage of the xenoberyciform genus *Gibberichthys* Parr (1933). *Kasidoron edom* Robins and de Sylva (1965) is treated as the prejuvenile stage of *Gibberichthys pumilus* Parr (1933). *Kasidoron latifrons* Thorp (1969), described from a prejuvenile specimen from the western Indian Ocean, is confirmed to be a separate species, *G. latifrons*; it is now known from the Indian Ocean and the western and southwestern parts of the Pacific Ocean. Ontogenetic changes from the larval stage to the adult are discussed and illustrated for *G. pumilus*, particularly the development and loss of the pelvic appendage—a modified third pelvic fin ray—and the development of crests on the head. The prejuvenile stage is found in epipelagic waters, and adults apparently occur in the lower mesopelagic and perhaps upper bathypelagic levels; adults probably do not undergo daily vertical migration. Additional notes on biology are included.

INTRODUCTION

A new family of fishes, the Kasidoroidae, was established by Robins and de Sylva (1965) for a small western Atlantic species characterized by a peculiar pelvic appendage, a modified third pelvic fin ray. They included the family in the order

Mirapinniformes. Robins (1966) provided additional comments on the family and order. Myers and Freihofer (1966) compared the family Kasidoroidae (incorrectly spelled by them as Kasidoridae) with their family Megalomycteridae. Greenwood et al. (1966) listed the family Kasidoridae (*sic*) in the suborder Mirapinnatoidei, order Cetomimiformes. However, Rosen and Patterson (1969: 456) suggested that, "from illustrations of this fish [*Kasidoron edom*] and a brief examination of the holotype we are convinced that it is very closely related to, and may be only the larva of, the beryciform *Gibberichthys pumilus*, with which it agrees in al-

most every character. . . . *Kasidoron* is therefore a beryciform. . . ." Rosen and Patterson did not elaborate further. A second species of *Kasidoron*, *K. latifrons*, was described by Thorp (1969) from off Zanzibar in the western Indian Ocean.

During the period 1969–1972, we were able to examine specimens referable to *Kasidoron edom* collected since the description of that species and many adult specimens identifiable as *Gibberichthys pumilus*. Our study of these specimens confirmed that *Kasidoron edom* indeed represented the prejuvenile stage of *Gibberichthys pumilus*, and we were thus able to trace ontogenetic changes and to provide information on biology and distribution. Our paper was ready to publish in 1972 and was cited as in press by Ebeling and Weed (1973: 412, footnote) in their treatment of the family Gibberichthyidae in the series titled "Fishes of the western North Atlantic." One dilemma caused us to withhold the paper at that time—this involved specimens from areas other than the Atlantic. At that time (1972) we had an adult specimen from the western Indian Ocean and a small postlarval specimen from the Molucca Sea. The adult was not in good condition and the description of *latifrons* was based on a prejuvenile which seemed to be somewhat different from the Atlantic prejuveniles available to us. Was *latifrons* a separate species?

In 1973 Dr. John Paxton made available to us an adult specimen in excellent condition which was collected from the south-central Pacific, and, as noticed by Dr. Paxton, his specimen seemed to differ noticeably from Atlantic adults in having smaller scales, among other features. In 1975 Dr. Bruce Robison made available to us an adult collected in the Halmahera Sea during the R/V Alpha Helix S.E.A.L. Expedition; he subsequently provided a second specimen from the same source. Recently Paxton informed us of an adult specimen in good condition collected by the R/V Galathea off Madagascar which he located in the Zoological Museum in Copenhagen. At last it was possible to compare an adult in good condition from the western Indian Ocean (type locality of *latifrons* was off Zanzibar) with adults from the Pacific and with *G. pumilus* in the Atlantic and to evaluate the status of *latifrons*.

Acknowledgments

Monica Abbott gave us valuable editorial assistance.

METHODS

The prejuvenile specimens are here termed the "kasidoron" stage, although subsequent workers may wish to disregard this term. The kasidoron stage is characterized by the presence of a unique pelvic appendage, and we confine the term to specimens possessing the appendage. The terminology "prejuvenile" comes from Hubbs (1958) as modified by Mansueti and Hardy (1967).

The last two elements in the dorsal and anal fin are counted as one ray. The first elements in the dorsal and anal fin become spinous when the fish is between 20 and 30 mm standard length (SL). The fin-ray counts of adults are taken as the number of spinous points or spines plus soft rays (see text).

Measurements are those commonly used to describe teleost fishes with a few modifications. Measurements originating from the anterior end of the fish are taken from the most anterior point of the left premaxillary. Head length is measured to the posteriormost tip of the upper opercular spine. Orbit diameter is the interior diameter of the bony orbit measured in a horizontal line. Measurements of prejuvenile specimens were made with an ocular micrometer. The third pelvic ray is measured to the tip of the ray without the pelvic tree, and the stalk of the pelvic tree is measured from the tip of the pelvic ray to the end of the main stalk. Many adults were variously damaged during capture, and some measurements are, therefore, inaccurate. Measurements of adults were usually taken to the nearest 0.5 mm. Original data used to prepare Figures 8–13 are on file at the California Academy of Sciences.

Abbreviations of depositories of specimens are as follows: AMNH—American Museum of Natural History, New York; AMS—Australian Museum, Sydney; ANSP—Academy of Natural Sciences of Philadelphia; BMNH—British Museum (Natural History), London; BOC—Bingham Oceanographic Collection, Yale University; CAS—California Academy of Sciences, San Francisco; MCZ—Museum of Comparative Zoology, Harvard University; SIO—Scripps Institution of Oceanography, La Jolla; UMML—University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami;

USNM—United States National Museum of Natural History, Washington, D.C.; ZMUC—Zoological Museum, University of Copenhagen.

MATERIAL EXAMINED

(Number of specimens and their standard length [mm] in parentheses.)

Gibberichthys pumilus

Kasidoron stage (depths of capture are as given by the collecting agency and are approximate estimates based on wire out and wire angle; these specimens were collected with 1-meter and 2-meter plankton nets): ANSP 102061 (1; 21.2, holotype of *K. edom*), 28°27′ to 28°25′N, 73°42′W, 15 m over bottom of 4462 m, PILLSBURY sta. 165, 2235–2335 hrs, 7 Aug. 1964. ANSP 102062 (1; 15.7, paratype of *K. edom*), taken with the holotype. UMML 16213 (1; 7.8, paratype of *K. edom*), 32°46′N, 64°33′W, 8 m over 2743 m, PILLSBURY sta. 144, 2025–2115 hrs, 3 Aug. 1964. UMML 16214 (1; 12.1, paratype of *K. edom*), 28°30′ to 28°27′N, 73°39′ to 73°42′W, 1–2 m over 4462 m, PILLSBURY sta. 164, 2115–2215 hrs, 7 Aug. 1964. UMML 28806 (1; 15.3), 30°00′N, 68°00′W, 16 m over 5014 m, PILLSBURY sta. 1053, 2109–2143 hrs, 24 Aug. 1969. ZMUC P41630 (1; 7.5), 21°50′N, 50°12′W, 100 m wire out, DANA sta. 3543 III, 2145 hrs, 12 Aug. 1928. ZMUC P41631 (1; 9.0), 24°48′N, 53°47′W, 17 m wire out, ST. JAN sta. 543, 1930 hrs, 6 Aug. 1912. ZMUC P41632 (1; 11.1), 24°10′N, 67°00′W, 77 m wire out, AG PETERSON sta. 803, 1900 hrs, 21 Sept. 1914.

Adults: CAS 14564 (2; 69 and 87, cleared and stained), 7°41′N, 53°48′W, 677 m, OREGON II sta. 10606, 21-m shrimp trawl, 10 May 1969. CAS 14565 (3; 49, 53, and 71.5) and BMNH (1; 57.5), 29°16′N, 86°55′W, 640 m, OREGON II sta. 10913, 58-m shrimp trawl, 12 Feb. 1970. FMNH 82924 (1; 80.5), 7°49′N, 54°22′W, 732 m, OREGON II sta. 10604, 21-m shrimp trawl, 10 May 1969. CAS 14566 (1; 91.5), 17°42′N, 63°58′W, 741 m, OREGON II sta. 10832, 21-m shrimp trawl, 3 Dec. 1969; CAS 37920 (1; 85), 7°41′N, 53°57′W, 735 m, OREGON II sta. 10621, 30-m shrimp trawl, 16 May 1969. CAS 14567 (2; 63 and 78) and CAS 14568 (1; 82.5, nerve preparation), 7°35′N, 53°29′W, 658 m, OREGON II sta. 10608, 39-m shrimp trawl, 11 May 1969. CAS 14569 (1; 85.5), 29°09′N, 87°58′W, 841 m, OREGON II sta. 10650, 68-m shrimp trawl, 25 June 1969. CAS 14570 (1; 83.5) and UMML 7041 (4; 57, 72.5 82.0, and 83.5), 29°10′N, 87°55′W, bottom depth 933–732 m (fishing depth uncertain), OREGON sta. 2399, 12-m mid-water trawl, 4 Feb. 1959.

The following additional adults were used in the map of distribution but were not examined in detail: MCZ 44211 (3 specimens), 7°46′N, 54°00′W, 732 m, OREGON sta. 4299, 20-m shrimp trawl, 23 Mar. 1963. USNM 187664 (1), 29°54′N, 80°11′W, 320–329 m, SILVER BAY sta. 3661, 24-m flat trawl, 16 Jan. 1962. UMML uncat. (1; frozen), 20°40′ to 20°42′N, 73°48′ to 73°40′W, est. depth 800–1100 m over 1463–2304 m, PILLSBURY sta. 1174, midwater trawl, 0441–0945 hrs, 29 June 1970. USNM 187665 (1), 29°11′N, 87°47′W, 832 m, OREGON sta. 3218, 18/24-m semi-balloon trawl, 9 Feb. 1961. Plus literature reference to one from OREGON sta. 1425, 29°04′N, 88°05′W, 914 m, 24 Sept. 1955. Plus the following USNM uncat. lots: OREGON sta. 3654 (1), 29°08.5′N, 88°00.5′W, 732–750 m, 12-m flat trawl, 25 July 1962. OREGON sta. 3660 (1), 29°10′N, 87°57′W, 658–732 m, 12-m flat trawl, 27 July 1962. OREGON sta. 3669 (1), 28°51.5′N, 88°39′W, 622 m, 12-m flat trawl, 29 July 1962. OREGON sta. 3670 (4), 29°00.5′N, 88°22′W, 732 m, 12-m flat trawl, 30 July 1962. OREGON sta. 4902 (2), 09°02.4′N, 76°31.5′N, 732 m, 20-m shrimp trawl, 28 May 1964. MISS VIRGINIA, no sta. (1), 29°10′N, 79°50′W, 180–200 m, Mar.–Apr.
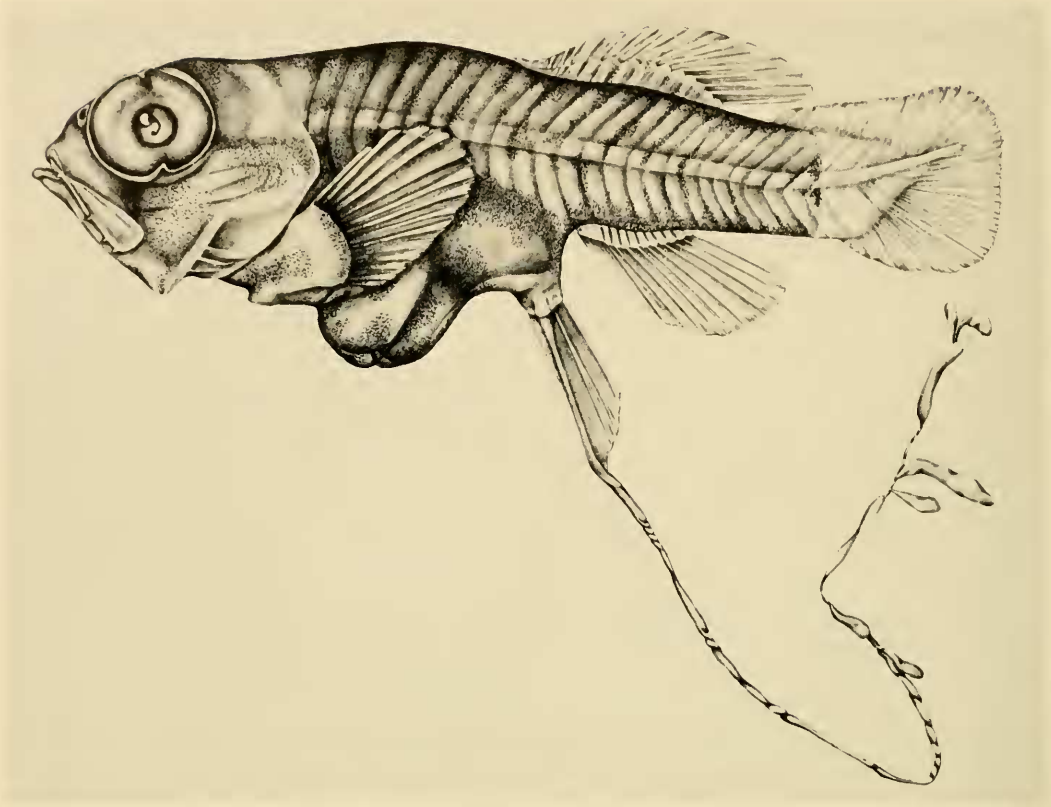
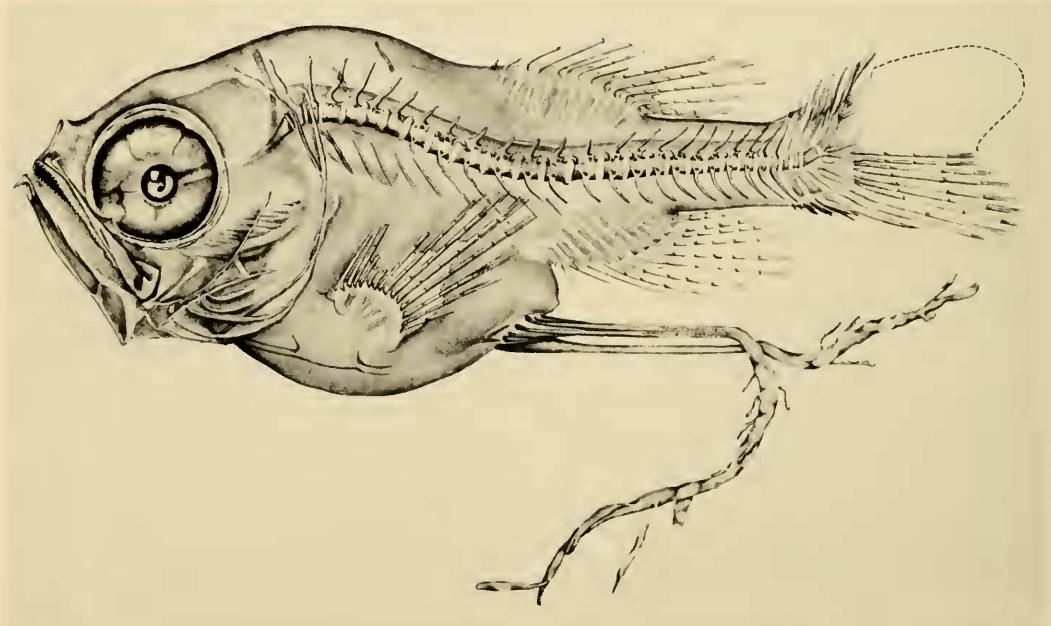FIGURE 1. *Gibberichthys pumilus*, kasidoron stage, 7.5 mm SL, ZMUC P41630.

FIGURE 2. *Gibberichthys pumilus*, kasidoron stage, 11.1 mm SL, ZMUC P41632.

1952. Plus the specimens reported by Parr (1933): BOC 2838 (1; 31.5, holotype of *G. pumilus*) 21°44'N, 72°43'25"W, 2134 m wire out, PAWNEE sta. 48, about 2127 hrs, 6 Apr. 1927. BOC uncat. (1, 91), 25°39'N, 77°18'W, 1050 or 1100 m to surface, triangular midwater trawl, ATLANTIS sta. 1478, 20–21 Feb. 1933.

Gibberichthys latifrons

Kasidoron stage: ZMUC P41633 (1, 7.8), 2°17'N, 126°48.5'E, 50 m of wire out, DANA sta. 3744 V, 2110 hrs, 7 July 1929. (Plus original description of *K. latifrons*, type locality off Zanzibar.)

Adults: USNM 205551 (1; 112), 16°44'S, 43°44'E, 58 m, shrimp trawl, ANTON BRUUN cruise 8, sta. 407J, 15 Oct. 1964. ZMUC P41634 (1; 124), off Madagascar, 11°43'S, 49°09'E, 1300 m, GALATHEA Expedition 1950–52, sta. 220, 1 Mar. 1951. AMS I.15999-001 (1; 103), 11°17'S, 142°47'W, 0–1040 m, 3-m IKMT, (ORSTOM) CORIOLIS sta. CARIDE III-17, 7–8 Feb. 1969. CAS 37918 (1; 80), Halmahera Sea, 0°10.5'S, 128°33.3'E, 750–1000 m, opening and closing 2.4-m Robison midwater trawl, ALPHA HELIX, S.E.A.L. Expedition, sta. 142, 1200–1400 hrs, 20 May 1975. CAS 37919 (1; 89.6), Halmahera Sea, 0°08.9'S, 128°40.0'E, 0–960 m, 2.4-m Robison midwater trawl, ALPHA HELIX, S.E.A.L. Expedition, sta. 137, 0955–1300 hrs, 19 May 1975.

COMPARISON OF *KASIDORON EDOM* WITH *GIBBERICHTHYS PUMILUS*

Though a complete size series of specimens is not available, it is possible to show that *Kasidoron edom* is the prejuvenile stage of *Gibberichthys pumilus*. Evidence comes especially from metamorphosis of the pelvic appendage, examination of ontogenetic changes in the development of crests on the head, similarity of meristic features, and other characters. These are discussed below.

Pelvic appendage.—The most striking feature of the kasidoron stage is the presence of a peculiar pelvic appendage (pelvic arborescence of Robins and de Sylva 1965). This structure is described in detail by Robins and de Sylva (1965) and Robins (1966). The pelvic appendage is a highly modified third pelvic ray which, according to Robins and de Sylva (1965: 192), is "... fitted at its tip with a long, round stalk to which attach large, hollow, leaf-like sacs." The pelvic appendage they illustrated was partially reconstructed and seems to have been an even larger arborescence (see also Thorp 1969, Fig. 1, for *G. latifrons*). Additional material available to us shows the development of this structure (Figs. 1–3). The pelvic tree is only partially developed in the 7.5-mm specimen (Fig. 1) and an 11.1-mm specimen (Fig. 2), and it then proliferates rapidly in size and complexity as shown in a 15.3-mm specimen (Fig. 3). (Further embellishment is found in the 21.0-mm holotype

of *Kasidoron latifrons* [Thorp 1969: Fig. 1].) The 31.5-mm holotype of *Gibberichthys pumilus* lacks the pelvic appendage, as do all of our larger specimens. However, we do find evidence in adults which suggests the fate of the pelvic appendage. In adults there is a discontinuity area part way up the third pelvic fin ray (Fig. 4) which is easily visible in cleared-and-stained specimens. We believe the expanded area represents the site of attachment of the pelvic appendage. It seems most likely that when the pelvic tree is lost the third pelvic ray continues to grow and segment normally, producing the result shown in Fig. 4. This discontinuity occurs only on the third pelvic ray as evidenced by examination of three cleared-and-stained specimens. The third pelvic ray in most juveniles and adults shows some evidence of deformity; it is the thickest, and is frequently slightly bent or distorted. The pelvic appendage is lost when the fish is between about 21 and 31 mm standard length, the limits of our material which have or do not have the appendage.

Body shape and coloration.—The 15.3-mm prejuvenile specimen (Fig. 3), the 31.5-mm holotype of *Gibberichthys pumilus* (Fig. 5), and large adults (Figs. 6 and 7) show the changes in body shape with growth. Measurements (Figs. 8–13) reveal that there is a constant growth rate of most body parts when compared with standard length, but different slopes of the growth curves cause different apparent effects. For example, the orbit increases in diameter very slowly as the fish grows, so that the orbit is nearly one-half the head length in prejuvenile specimens but one-seventh or one-eighth of the head length in adults. Measurements of some body parts when plotted against standard length show slight changes in growth rates at about a size where the pelvic appendage is lost, and presumably when the juvenile specimens move to a deeper habitat. For example, the snout length (Fig. 11) grows slowly in prejuvenile specimens, subsequently increases rapidly, and then shows a slower constant growth rate in adults. Head length (Fig. 13) seems to show a similar change in growth rate. The length of the third pelvic fin ray (Fig. 12) increases very slowly, thereby becoming very small proportionally in larger specimens, but some variability in our measurements results from the third ray being broken in large specimens; the development of the pelvic appendage (Fig. 12) is ex-
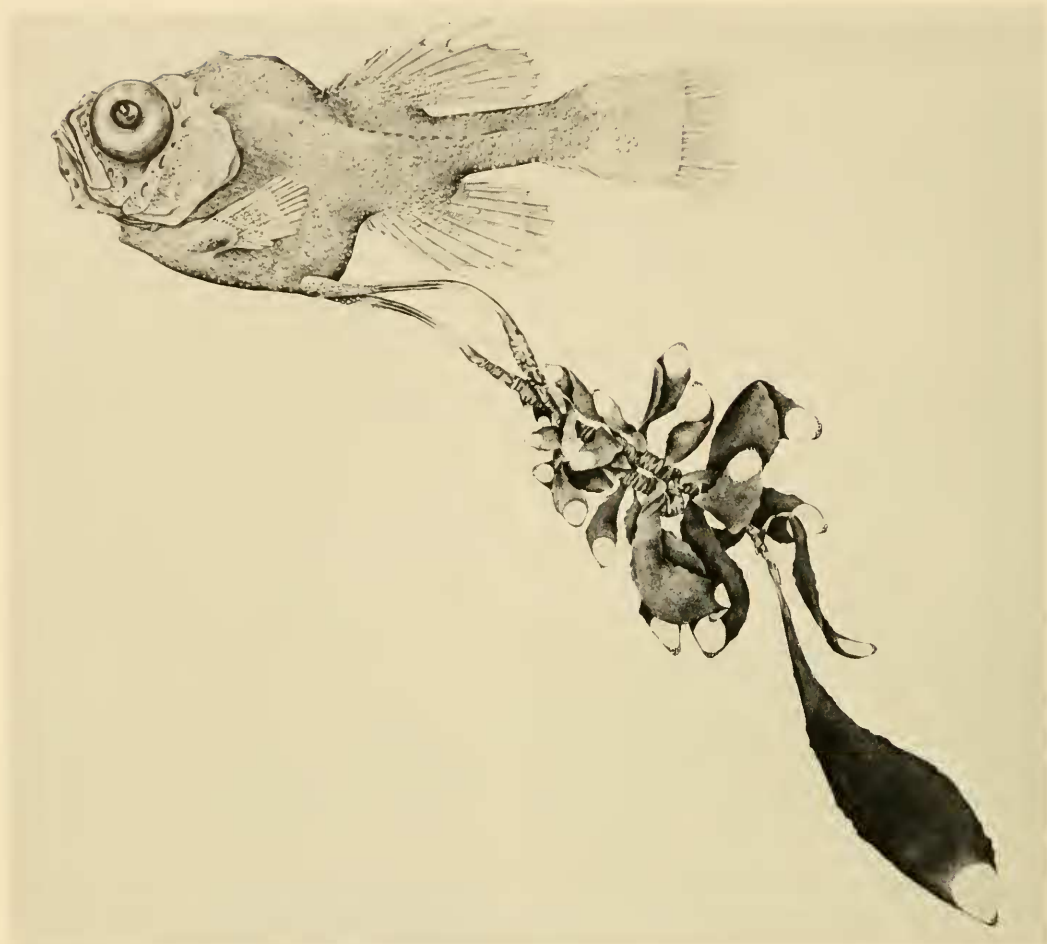
FIGURE 3. *Gibberichthys pumilus*, kasidoron stage, 15.3 mm SL, UMML 28806.

tremely rapid. Other measurements are given in Figs. 8–13.

The most notable changes in body shape, besides proportional differences in eye size, are the shift in position of the mouth from an oblique position to a more terminal one, and a change in the orbit from a sub-superior to a more lateral position. The proliferation of thin, spiniferous crests over the head of the prejuveniles and juveniles is accompanied by closure of the cavernous sulci permeating the head. This transition is observed in the fenestration of the su-
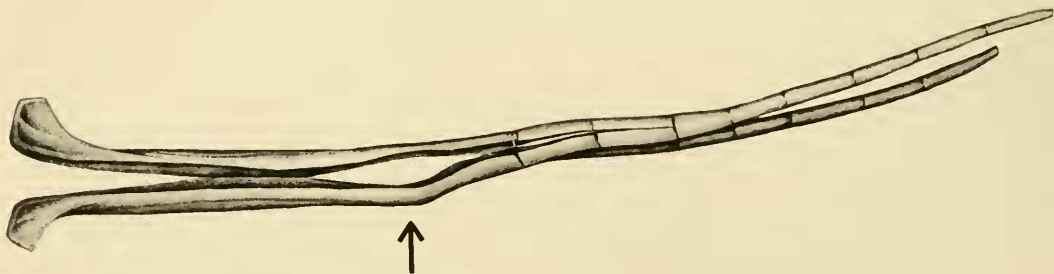
FIGURE 4. Lateral view of the third pelvic fin ray of adult *Gibberichthys pumilus*. Arrow indicates discontinuity (see text).
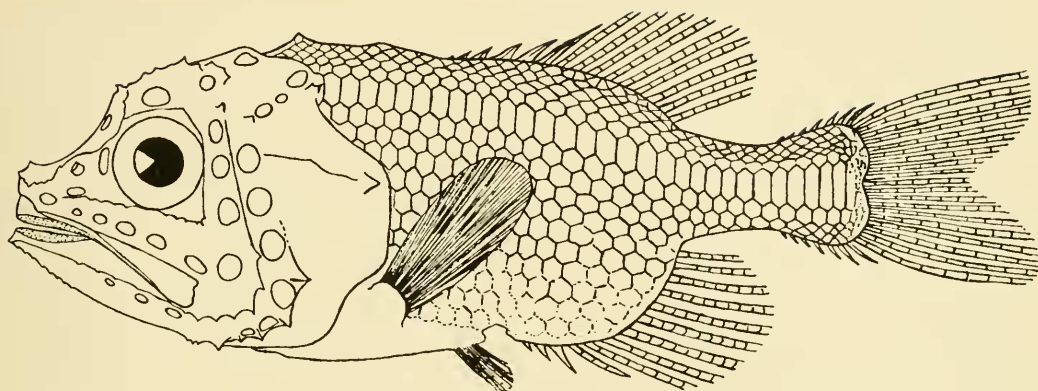
FIGURE 5. Holotype of *Gibberichthys pumilus*, 31.5 mm SL, after Parr, 1933.
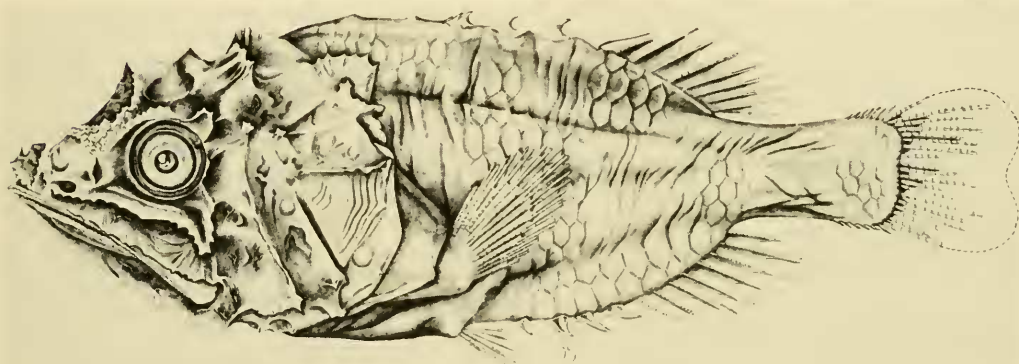
FIGURE 6. *Gibberichthys pumilus*, 82 mm SL, UMML 7041.
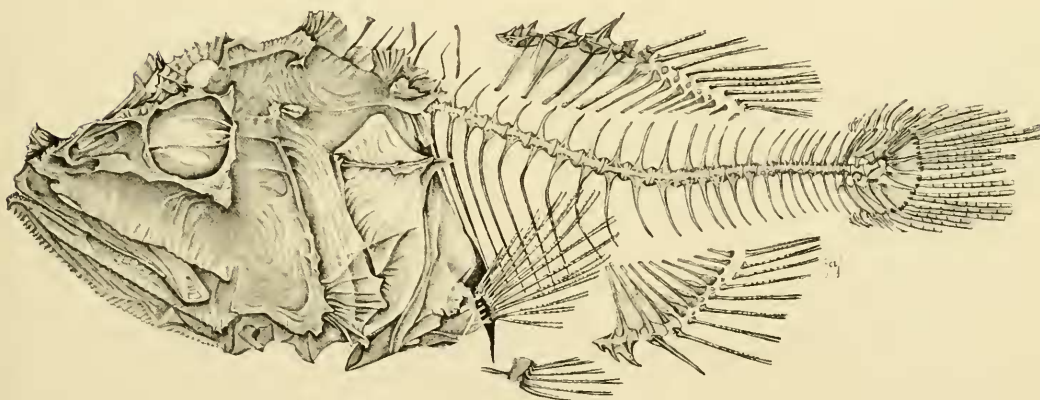
FIGURE 7. *Gibberichthys pumilus*, 87 mm SL, CAS 14564, cleared and stained.
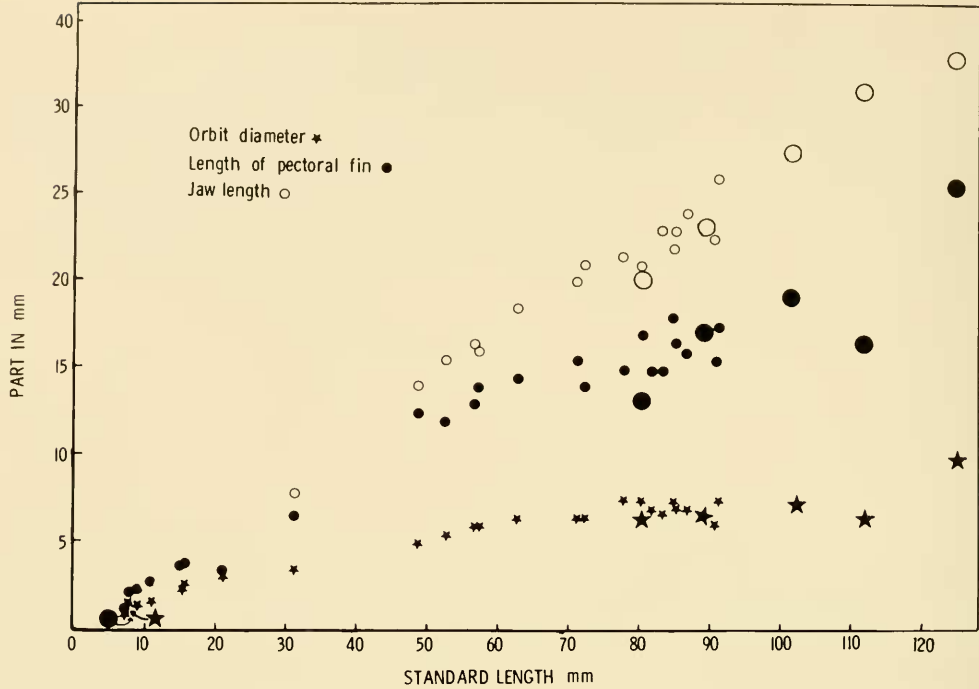
FIGURE 8. Orbit diameter, length of pectoral fin, and jaw length in *Gibberichthys pumilus* and *G. latifrons* (enlarged symbols).
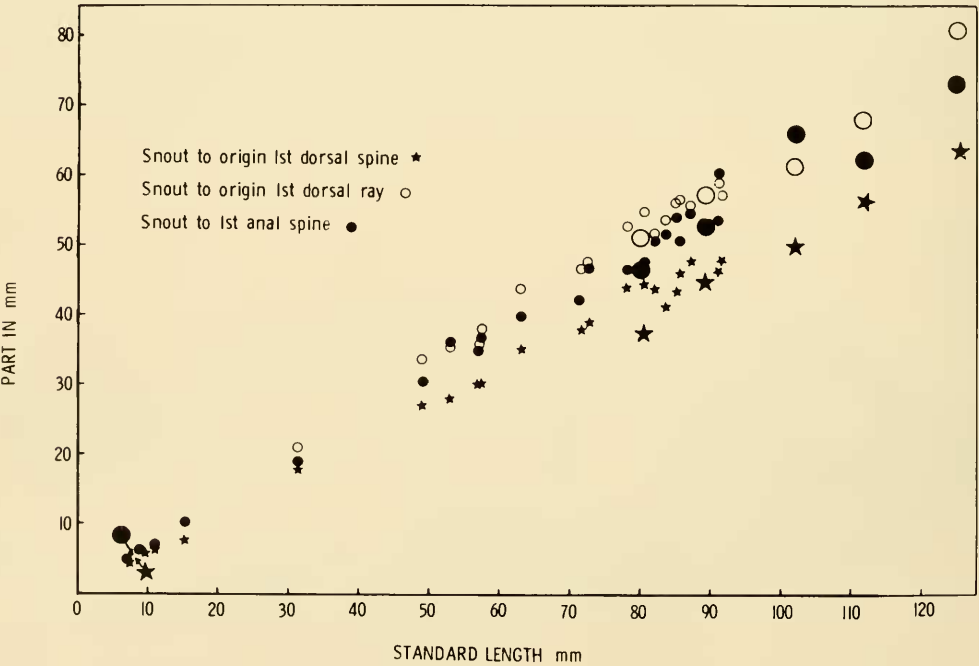
FIGURE 9. Lengths of snout to origin of first dorsal spine, snout to origin of first dorsal soft ray, and snout to origin of first anal spine in *Gibberichthys pumilus* and *G. latifrons* (enlarged symbols).
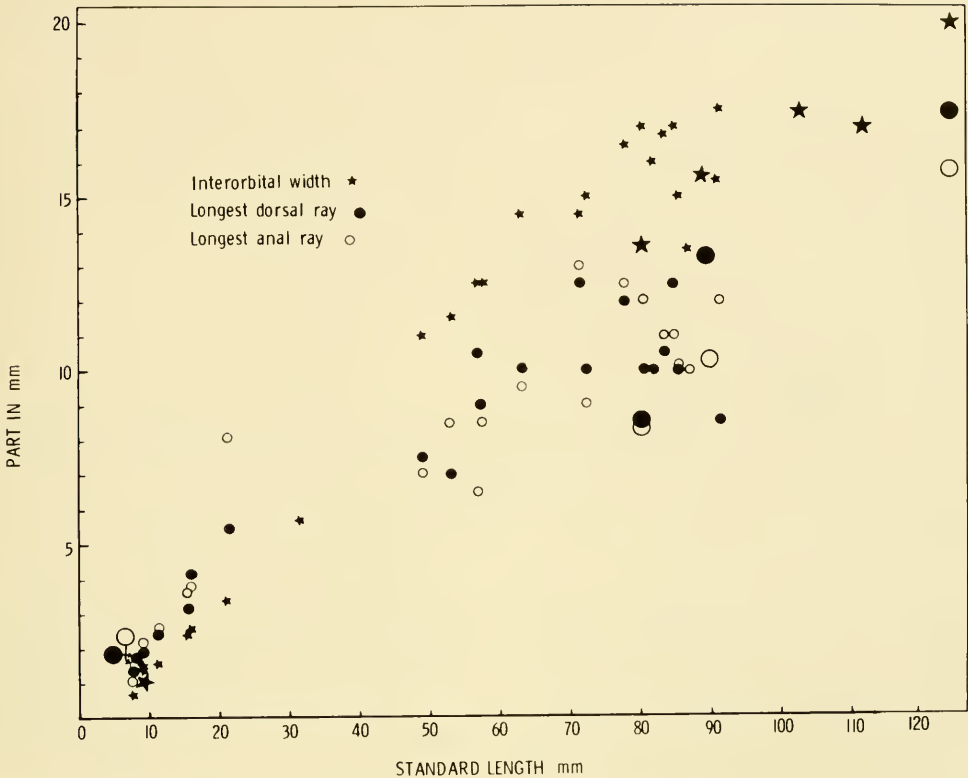
FIGURE 10. Interorbital width, longest dorsal soft ray, and longest anal soft ray in *Gibberichthys pumilus* and *G. latifrons* (enlarged symbols).

praorbital region of a 15.3-mm specimen (Fig. 14a) and is also visible in the same area in adults (Fig. 14b). Similarly, the bony crests so characteristic of the head of adults (Fig. 6–7, 14) are just observable in the internasal region of a 15.3-mm specimen (Fig. 15). As growth continues, the relative position of several cranial bones changes concomitantly to correspond with the lengthening and flattening of the head. These include the change in position of the maxillary to accommodate a rearward shift in the angle of the preopercle and opercle. The maxillary is unsheathed in prejuveniles, but growth of the circumorbital bones partially sheathes the maxillary in larger specimens.

The height of the lumps on the midline behind the head (one character used by Thorp (1969) to distinguish *K. latifrons* from *K. edom*) is due to three interneural (predorsal) bones (see especially Figs. 3, 6–7; see Thorp, 1969, Fig. 1, for *G. latifrons*). Their manifestation as lumps seems more prominent in the prejuveniles than in

adults, but this variability may also result from shrinking with preservation.

Little ontogenetic change in coloration occurs; both juveniles and adults are black. The eyes of a freshly captured adult (PILLSBURY sta. 1174) glowed red when a flashlight was shined on them.

Meristic characters.—Counts of dorsal, anal, pelvic, and pectoral rays are similar both in the kasidoron stage and in adults (Table 1). The anterior fin elements in the dorsal and anal fins become spinous when the fish reaches a size between our largest kasidoron stage (21.2 mm) and the holotype of *Gibberichthys pumilus* (31.5 mm). The anterior spines are fixed on broad, firm bases; usually only the last spine is movable. There are usually 6 spinous points in the dorsal fin and 4 in the anal fin. The first plate of the anal fin has 2, while subsequent plates each bears 1 spinous point. Our adult specimens average about 1½ "ray" higher in dorsal "fin-ray" count when spinous points plus soft rays of adults are
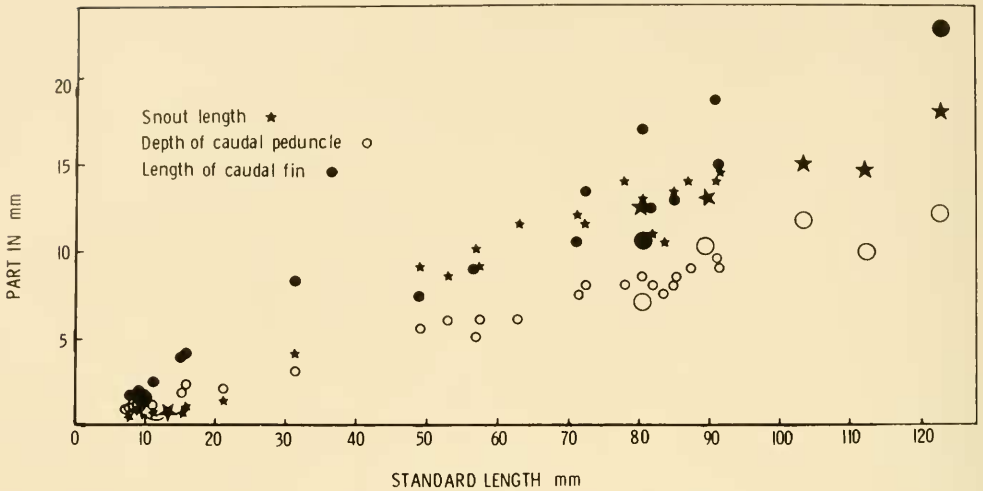
FIGURE 11. Snout length, depth of caudal peduncle, and length of caudal fin in *Gibberichthys pumilus* and *G. latifrons* (enlarged symbols).

compared with fin rays of prejuveniles. We believe the first plate of the dorsal and anal fin probably forms from fusion of two fin rays, but usually an extra spinous point develops on the first plate of the dorsal fin which results in the higher dorsal "fin-ray" count of adults. (If three fin rays make up the first plate when it bears three spinous points, then at least one of these elements is not distinguishable in prejuveniles.)

Pelvic rays are usually 6, with the first ray spinous in adults. One specimen, the 7.8-mm paratype of *K. edom*, had only 5 countable pelvic elements, as did one adult. Procurrent caudal rays become spinous after the kasidoron stage;

they usually number 7 above and 6 below. Principal caudal rays usually number 19, with one unbranched above and one below. The caudal fin structure of an adult is illustrated in Fig. 16.

Vertebrae number 29–30 in three postlarvae and 20 adults of *G. pumilus* examined for this character.

Pyloric caeca.—Pyloric caeca number 12–13 in adult specimens examined for this feature with about 9 exposed and 3 or 4 under the liver; most caeca form one whorl, but some caeca lie farther down the intestine. In the holotype of *K. edom* there were 9 caeca arranged in a single whorl
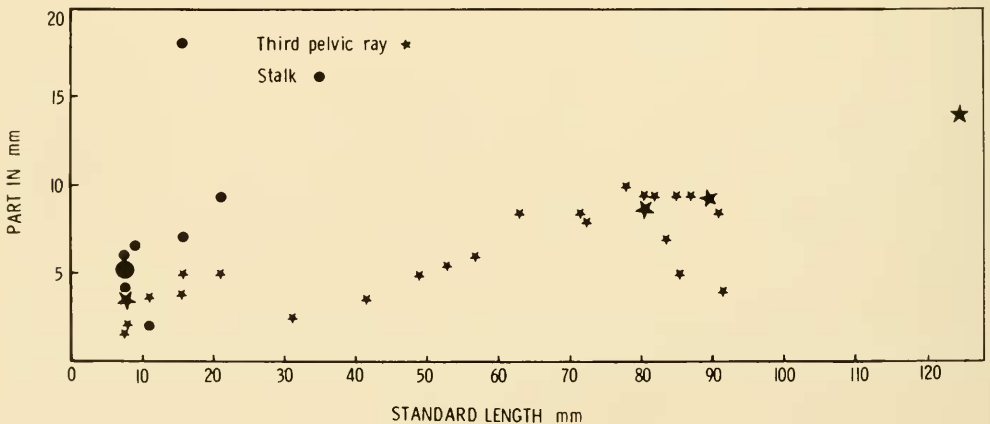
FIGURE 12. Length of third pelvic fin ray and length of the pelvic appendage in *Gibberichthys pumilus* and *G. latifrons* (enlarged symbols).
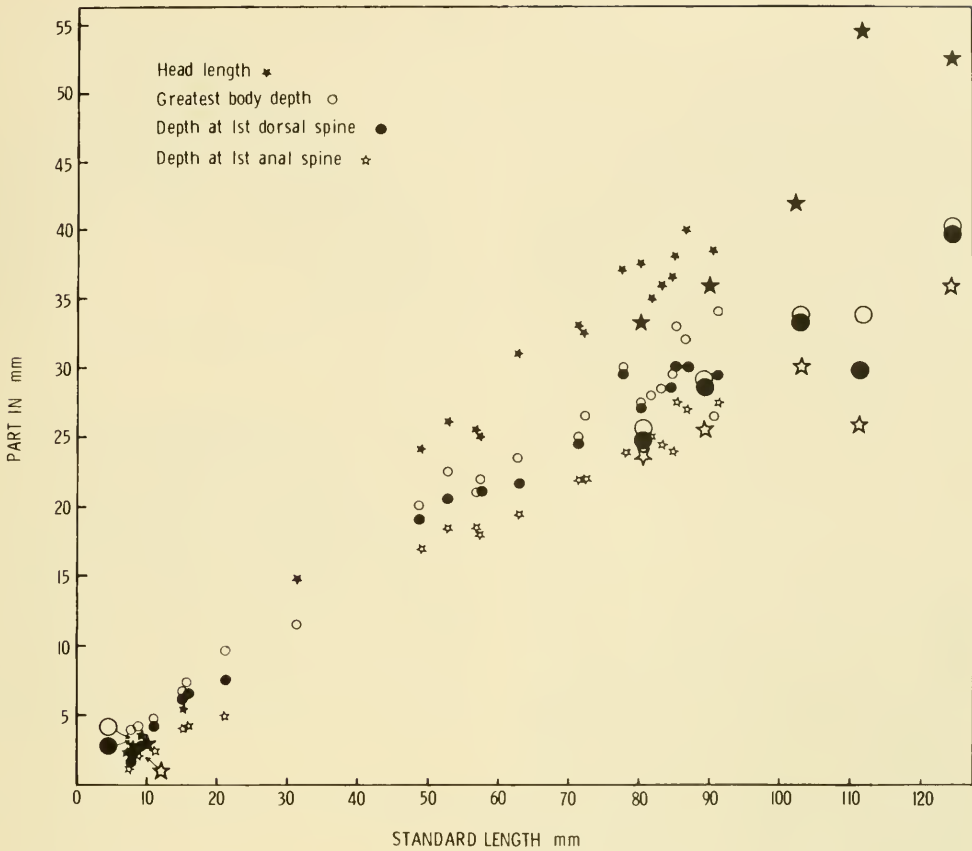
FIGURE 13. Head length, greatest body depth, body depth at origin of first dorsal spine, and body depth at origin of first anal spine in *Gibberichthys pumilus* and *G. latifrons* (enlarged symbols).

(Robins and de Sylva, 1965: 196), but possibly some caeca were rubbed off during examination of this very small specimen, or they were not yet developed. In the prejuvenile specimens and in adults the caeca are pale and long.

Gill rakers.—Counts of gill rakers are particularly difficult to make on the prejuvenile specimens, but the number of rakers on the first arch in these specimens and in adults (Table 1) are comparable. Counts for adults are 5–6 above, one at the angle, and 13–15 on the lower arch, total 18–22 (mean = 20.2, N = 15).

Lateral line.—The lateral line in type specimens of *K. edom* was reported as composed of about 32 vertical rows of raised papillae (Robins and de Sylva 1965: 195). Most skin on the body was rubbed off during caputre of our adult specimens, but in some specimens sufficient skin is intact to

permit us to determine that adults also have a lateral line composed of vertical rows of raised pores, each row with about 6 to 8 pores. We are unable to give an exact count of the number of vertical rows, but they are spaced approximately as in the holotype of *K. edom*. Parr (1934: Fig. 37) illustrated the vertical rows of pores and found 28 rows in his 91-mm specimen.

Swimbladder.—Robins and de Sylva (1965: 196) reported that *K. edom* has a well developed swimbladder restricted to the anterior portion of the body cavity. The swimbladder in adult specimens is moderate, thin walled, and lies in the anterior half or two-thirds of the body cavity. It is partially filled with fat in adults.

In summary, differences in the above features can be attributed to ontogenetic changes, features which are the same or nearly so in the small specimens and adults, and those differences
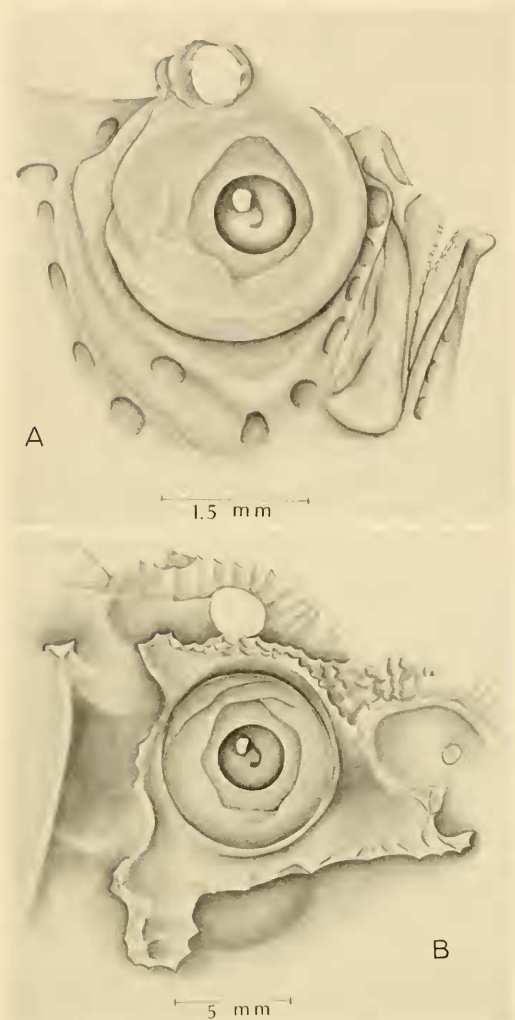
FIGURE 14. Lateral view of oribital region in (A) postlarva, UMML 28806, 15.3 mm SL, and (B) small adult, UMML 7401, 72.5 mm SL, of *Gibberichthys pumilus*.

FIGURE 15. Dorsal view of nasal region in (A) postlarva and (B) a small adult of *Gibberichthys pumilus* (same specimens as in Fig. 14).

which may result from error because of the small size of prejuveniles examined. We believe that there can be no doubt that *Kasidoron edom* is the prejuvenile stage of *Gibberichthys pumilus*.

SPECIES OF THE GENUS
GIBBERICHTHYS

Since *Kasidoron edom* is the prejuvenile of *Gibberichthys pumilus*, then *Kasidoron latifrons* Thorp from the western Indian Ocean is a prejuvenile of the same species or a separate species. We have available only six specimens from outside the Atlantic; Ebeling and Weed (1973) re-

ported one non-Atlantic specimen, and the holotype of *latifrons* brings to eight the total non-Atlantic specimens known.

The differences between the holotype of *latifrons* and prejuveniles of *pumilus* as given by Thorp (1969) are as follows: the lumps behind the head are larger and the body deeper in *latifrons*, and *latifrons* has a minute extra pore in the head lateralis system, no small cycloid scales along the lateral line, a lower gill-raker count, slight differences in measurements, and differences in the pelvic appendage. The dorsal lumps are caused by three interneural (predorsal) bones, and the prominence of the lumps is probably related to some extent by condition or shrinkage with preservation. We are unable to assess the minute extra head pore. The number of gill rakers and other counts (Table 1) fall within the range of *pumilus* based on our material. We are unable to provide much additional information on differences in the pelvic appendage (see Thorp 1969: 68–69) but suspect this to be a structure which is variable in details; no Atlantic prejuvenile had

TABLE 1. COUNTS FOR SPECIMENS OF *Gibberichthys pumilus* AND *G. latifrons*.

	Dorsal fin rays																
	Prejuveniles				Spinous points + rays in adults							Total (Adults)				
	12	13	14	15	5	6	7	8	+	8	9	13	14	15	16	17
G. pumilus[1]	4	3	1	1	6	9	–	–		5	10	2	7	6	–	–
G. latifrons[2]	1	–	1	–	–	1	3	1		–	5	–	–	1	3	1

	Anal fin rays													
	Prejuveniles			Spinous points + rays in adults						Total (Adults)			
	10	11	12	4	5	+	7	8	9	11	12	13	14
G. pumilus[1]	2	2	5	13	2		7	7	1	6	7	2	–
G. latifrons[2]	–	2	–	–	5		2	2	1	–	2	2	1

	Pectoral rays (left side)			Pelvic rays[3] (left side)		Gill rakers[3] (left side)				
	13	14	15	5	6	18	19	20	21	22
G. pumilus[1]	4	16	4	2	21	3	3	6	4	5
G. latifrons[2]	1	6	–	–	7	1	3	–	–	2

[1] Includes Parr's (1933) count for one specimen.
[2] Includes Thorp's (1969) count for holotype.
[3] Some small specimens not included.

the arborescence as well developed as Thorp's specimen, and the differences in pigmentation of the "leaves" as presented by Thorp may prove to be real differences.

Comparison of the five non-Atlantic adults with the larger series of Atlantic adults reveals virtually no differences between them in counts and measurements (see Table 1; Figs. 8–13). Our largest specimen of *G. pumilus* is 91.5 mm in standard length while the largest specimen of *G. latifrons* is 124 mm SL. One major difference was pointed out by Dr. John Paxton when he forwarded the AMS specimen to us. The scales on the body appeared to be considerably smaller in his specimen from the southwestern Pacific than in the specimen figured by Parr (1933). The skin and scales are more intact in our non-Atlantic specimens and all of the Atlantic adults are missing virtually all scales and much skin. We estimate that the scales in Atlantic specimens are about twice the size of scales in the non-Atlantic specimens. This difference is easily seen by comparing Parr's figure (1933: Fig. 1; reproduced here as Fig. 5) and our Figure 6, with the excellent rendition of an adult *latifrons* in Ebeling and Weed (1973: Fig. 12). (Parr's illustration showing a row of enlarged scales along the lateral line probably is inaccurate, and we believe that two slightly enlarged scales are present, rather than one enlarged and elongated (vertically) scale, and that both scales house papillae of the lateral line.)

Besides the difference in scale size, the Atlantic and non-Atlantic specimens differ in vertebral counts as given below:

Vertebrae	28	29	30	31
Atlantic specimens	5	18	–	–
Non-Atlantic specimens	–	–	2	3

Because of certain differences in prejuvenile features, and the differences in scale size and number of vertebrae, we recognize two species, *G. pumilus* from the Atlantic and *G. latifrons* from the western Pacific and Indian oceans.

SYNONYMIES

Prior literature may be summarized as follows:

Family GIBBERICHTHYIDAE Parr

Gibberichthyidae Parr, 1933: 1, 4–5 (type-genus *Gibberichthys* Parr, 1933; comparison with other beryciform families). Ebeling 1962: 11 (in Stephanoberyciformes). Ebeling and Weed: 1973. 397 et seq. (relationships). Greenwood et al. 1966: 398 (listed in order Beryciformes, suborder Stephanoberycoidei). Rosen and Patterson 1969: 456, 461
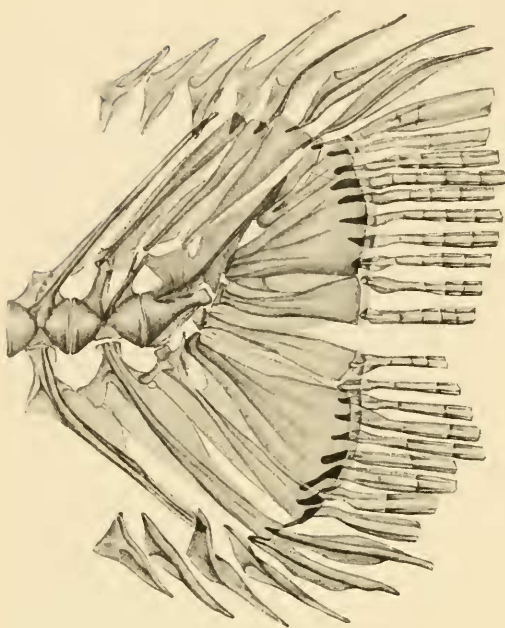
FIGURE 16. Caudal skeleton of *Gibberichthys pumilus*, CAS 14564, 87 mm SL.

(suggested *Kasidoron* was young of *Gibberichthys*; relationships). Rosen 1973: 469 et seq. (relationships).
Kasidoroidae Robins and de Sylva, 1965: 190 et seq. (typegenus *Kasidoron* Robins and de Sylva, 1965). Robins 1966: 696–701 (descriptive information, relationships).
Kasidoridae (*sic*), Myers and Freihofer 1966: 193–194 (compared with Megalomycteridae). Greenwood et al. 1966: 395 (listed in suborder Mirapinnatoidei, order Cetomimiformes).

Genus **Gibberichthys** Parr

Gibberichthys Parr, 1933: 5 (type-species *Gibberichthys pumilus* Parr, by original designation, monotypic).
Kasidoron Robins and de Sylva, 1965: 190 (type-species *Kasidoron edom*, by original designation, monotypic).

Gibberichthys pumilus Parr

Gibberichthys pumilus Parr, 1933: 5–6, Fig. 1 (type-locality 21°44′N, 72°43′25″W, 2134 m wire, 6 Apr. 1927, PAWNEE sta. 48: BOC 2838). Parr 1934: 35–36, Fig. 11 (description of 91-mm specimen; ATLANTIS sta. 1478; compared with holotype). Myers 1936: 118 (belongs near Stephanoberycidae). Springer and Bullis 1956: 66 (listed; Gulf of Mexico, OREGON sta. 1425). Grey 1959: 333–334 (description of a 47-mm specimen, 29°04′N, 88°05′W, 914 m, OREGON sta. 1425). Ebeling and Weed 1973: 412–414 (in part; figure and part of description is *G. latifrons*; family relationships).
Gibberichtys pumilus, Ebeling 1962: 11 (misspelled genus; agreed with Rofen that it was allied to melamphaeids).
Kasidoron edom Robins and de Sylva, 1965: 189 et seq., Figs. 1–2 (original description; types from near Bermuda and NE of Bahamas). Robins 1966: 696 et seq., Figs. 1–3 (additional information on *K. edom*; relationships). Voss and Sisson

1967: 393 (figure). Thorp 1969: 62 et seq. (compared with *K. latifrons*). Rass 1971: plate opposite p. 97 (figure; tips of pelvic appendage shown as luminescent).

Gibberichthys latifrons Thorp

Gibberichthys latifrons Thorp, 1969: 61–70, Figs. 1–4 (original description; type-locality near Zanzibar, 08°34′S, 41°37′E; good description; compared with *K. edom*).
Gibberichthys pumilus, Ebeling and Weed 1973: 412–414, Fig. 12 (good figure; did not distinguish *latifrons* from *edom*).

DISTRIBUTION AND BIOLOGY

Gibberichthys pumilus is now known from several localities in the western Atlantic (Fig. 17). *Gibberichthys latifrons* is known from the western Indian Ocean (3 specimens), the Halmahera Sea area (3), near Samoa (Ebeling and Weed 1973) (1), and west of the Marquesas Islands (1). We attribute the separate distribution of prejuveniles and adults in the Atlantic Ocean (Fig. 17) to an artifact of collecting methods and effort. The prejuveniles were captured in oceanic waters where University of Miami PILLSBURY operations were concentrated, and most adults were caught in coastal waters where OREGON and OREGON II trawling operations were conducted. We expect the species is widespread in the western Atlantic.

Lack of data from closing nets allows us only limited interpretation of the vertical distribution of adults. The prejuveniles are epipelagic, all captures being taken between near-surface waters and about 50 m. All captures were made at night and no specimens were taken in near-surface daylight tows. One might infer from the black coloration of the fish that prejuveniles may undergo diel migration at least into lower epipelagic or upper mesopelagic levels during daylight hours. Changes in morphology between the prejuvenile stage and the juvenile stage, which occur at about the time that the fish descend into the lower mesopelagic or upper bathypelagic levels, are discussed in an earlier section.

Capture of adults has been by use of both bottom trawls and midwater nets. The shallowest bottom trawl haul in the western Atlantic was in 320 m and the deepest in 841 m, with most in the range of 650–750 m. Additional collections of adults from vertical tows and non-closing midwater nets add limited information; one capture was estimated to be at 800–1100 m and another in 1050 or 1100 m. It would appear that the depth range of adults in the western Atlantic is roughly from 300
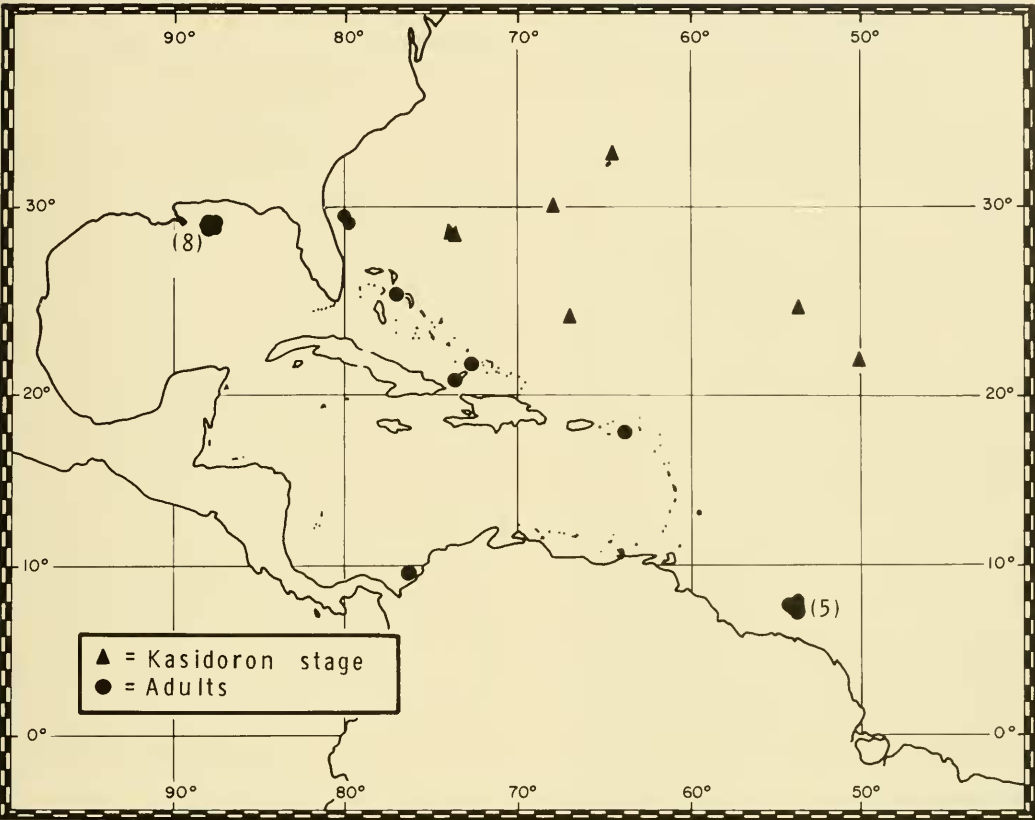
FIGURE 17. Distribution of *Gibberichthys pumilus* in the western Atlantic Ocean (symbols represent stations).

m to 1000 m; however, one adult of *latifrons* from the western Indian Ocean was collected at a depth of 58 m (correspondence with Leslie Knapp indicates that the depth of capture is accurate). The adult from the southwestern Pacific was from an oblique tow between 0 and 1040 m, and the one reported by Ebeling and Weed (1973) between 0 and 1000 m. The presence of fat in swimbladders of adults and the absence of captures in near-surface waters at night, where most trawl hauls for midwater fishes have been made, suggests that adults do not undergo vertical migration, at least not into near-surface waters.

The food of postlarval specimens was reported by Robins and de Sylva (1965: 200) as copepods, particularly calanoid copepods. Stomachs of 16 adults of *Gibberichthys pumilus* were removed and the contents examined. Fifteen specimens contained food, 13 of which had identifiable contents as follows:

Category	Number of stomachs in which organism was found
Amphipoda	
Gammaridea	
Lysianassidae	
Cyphocaris johnsoni	11
Hyperiidea	
Hyperiopsidae	
Hyperiopsis sp.	1
Copepoda	
Calanoida	
Eucalanidae	
Eucalanus elongatus	1
Metridiidae	
Pleuromamma abdominalis	1
Harpacticoida	1

The pelagic gammaridean *Cyphocaris johnsoni* was by far the most common food of adults, occurring in 11 stomachs, usually from 1 to 8 per stomach. Nearly all stomachs contained crustacean fragments, usually of amphipods. According to Vinogradov (1970: 209) the pelagic gam-

marids in the total plankton mass above 3000 m is negligible, but since these amphipods were common in stomachs and because other plankters were few, we suspect that *Gibberichthys pumilus* is selective in its food habits.

The use of the pelvic appendage deserves additional study. Robins and de Sylva (1965: 199) reported on the swimming behavior of a freshly captured specimen in a shipboard aquarium. They suggested that the pelvic appendage may mimic the nectosome of siphonophores. A more complete description of the pelvic appendage was given by Robins (1966: 698–700), particularly regarding microstructure. No sign of any specialized structure that could account for luminescence was found, and no muscle fibers or nerves were found associated with the stalk or "leaves." However, the epithelium on the tips of the pelvic appendage had been sloughed off in the specimen examined by Robins and de Sylva (1965) (personal communication from Mrs. Priscilla Rasquin Breder), so that epithelial luminescent structures could have been lost. A second specimen was observed alive by de Sylva (PILLSBURY sta. P-1053). The specimen lived for about four hours, swam only moderately, alternating bursts of active swimming near the surface with periods of quiet on the bottom. Its behavior appeared abnormal. Periodic examination of the specimen in the dark showed that the "leaf" tips, if luminescent, were not noticeably so, but the room was not completely dark. The tips of the fresh "leaves" were pale greenish yellow, a cast sometimes characteristic of luminous structures (see Nicol 1967, 1969). A color illustration which shows the presumed luminous nature of the epithelium of the tips is presented in Rass (1971: plate opposite p. 97). The simple nature of the pelvic appendage would seem to rule out voluntary control of the luminescence, but bacterial associations might be possible. (However, we would caution against illustrations depicting luminescence [e.g., Rass 1971] because it is quite possible that no luminescence is involved.) The apparent lack of muscles associated with the pelvic appendage renders it passive and would seem to limit its use to either mimicry as proposed by Robins and de Sylva (1965) or general deception, particularly when viewed from below or behind, or as a "cover" source which might attract food items. The arborescence in Thorp's specimen (1969: Fig. 1) resembles *Sargassum* weed more than in Robins' specimen (1966: Fig. 1).

Ripe gonads were found in two female specimens measuring 81 and 87 mm SL collected on May 10th. The eggs contain an oil globule. There is no evidence that the species is hermaphroditic.

REMARKS

The relationships of the family Gibberichthyidae deserve additional study. We agree with Ebeling and Weed (1973) that the family Gibberichthyidae seems to show closest relationships to the family Stephanoberycidae, and a more distant relationship to the Melamphaeidae. A brief examination of stephanoberycids and melamphaeids was made, and we found no indication that a prejuvenile pelvic appendage exists in any xenoberyciform group except *Gibberichthys*. Some melamphaeids, particularly postlarval specimens of the genus *Poromitra*, have extremely long pelvic fins with the individual rays branched many times and becoming hair-like distally. The family Gibberichthyidae is uniquely characterized by the presence of the pelvic appendage in postlarval specimens. It was separated by Norman (1957: 213) from melamphaeids and stephanoberycids on the basis of the presence of spines in the pelvic, dorsal, and anal fins in *Gibberichthys*, especially the rigid spines with broad, flattened basal plates in the dorsal and anal fins (see also Ebeling and Weed 1973). When one recalls that the soft fin rays of the kasidoron stage become the fin spines of *Gibberichthys*, it is not difficult to consider that similar transitions of rays to fin spines may also occur in other groups of deep-sea fishes which are suspected of bizarre metamorphoses.

We also briefly examined specimens of *Rondeletia bicolor* and were struck by the resemblance of this fish to *Gibberichthys*, as was Rofen (see Ebeling 1962: 11; Ebeling and Weed 1973: 399). Ebeling and Weed (1973: 399) discussed the problems surrounding placement of *Rondeletia* and the classification of three groups, their orders Xenoberyces (Stephanoberyciformes), Beryciformes, and Cetunculi (Cetomimiformes). Add to this the fact that Robins (1966) placed the postlarval *Kasidoron edom* in the Mirapinniformes. In turn he placed these near the Cetomimiformes, and noted that some of them were prejuveniles of cetomimids (Robins 1974), e.g. *Megalomycter*, *Ataxolepis* (C. R. Robins, personal communication). However, Rosen and Patterson (1969) removed *Kasidoron* to the Beryciformes (including

also the Cetomimoidei) but did not comment on the remainder of the mirapinniform fishes except to include them (op. cit.: 461) in the Lampridiformes. Nor does the reshuffling and reorganizing of these groups by Rosen and Patterson (1969) from the classification of Greenwood et al. (1966) advance our understanding of relationships except to move the Lampridiformes next to the Beryciformes and place all of them in the same superorder. Rosen (1973) has further reshuffled these and other groups and presented (op. cit.: 469) a working hypothesis that there is a group (iv) within a broad order Beryciformes containing the Barbourisiidae, Rondeletiidae, Gibberichthyidae, Cetomimidae, Mirapinnidae, Eutaeniophoridae, Megalomycteridae, Melamphaeidae, Stephanoberycidae, and Anoplogasteridae. It is apparent that the higher-category classification of these fishes remains uncertain.

Recent collections of deep-water fishes by many researchers are disclosing that our knowledge of metamorphosis of deep-water fishes is poorly known, and bizarre transformations involving more than one metamorphosis may be common in certain fish groups. Certainly, the identity of such groups as the Rosauridae, Megalomycteridae, Mirapinnidae, and Eutaeniophoridae should be re-examined, and some are being studied by other workers. It is possible that at least some of these represent prejuvenile stages of cetomimoid, berycoid, or other fishes.

Literature Cited

EBELING, ALFRED W. 1962. Melamphaidae I. Systematics and zoogeography of the species in the bathypelagic fish genus *Melamphaes* Günther. Dana Rep. Carlsberg Found. 58: 1–164, figs. 1–73.

———, AND WALTER H. WEED, III. 1973. Order Xenoberyces (Stephanoberyciformes). *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res., Yale Univ. 1 (pt. 6): xix + 698 pp.

GREENWOOD, HUMPHRY P., DONN E. ROSEN, STANLEY H. WEITZMAN, AND GEORGE S. MYERS. 1966. Phyletic studies of teleostean fishes, with a provisional classification of living forms. Bull. Am. Mus. Nat. Hist. 131(4): 339–456, pls. 21–23.

GREY, MARION. 1959. Deep sea fishes from the Gulf of Mexico with the description of a new species *Squalogadus intermedius* (Macrouridae). Fieldiana, Zool. 39(29): 323–346, figs. 54–57.

HUBBS, CARL L. 1958. *Dikellorhynchus* and *Kanazawaichthys*: nominal fish genera interpreted as based on prejuveniles of *Malacanthus* and *Antennarius*, respectively. Copeia 1958(4): 282–285.

MANSUETI, ALICE J., AND JERRY D. HARDY, JR. 1967. Development of fishes of the Chesapeake Bay region. An atlas of egg, larval, and juvenile stages. Part 1. Natural Resources Inst., Univ. Maryland. 202 pp.

MYERS, GEORGE S. 1936. A note on the stephanoberycid fishes. Copeia 1936(2): 118.

———, AND WARREN C. FREIHOFER. 1966. Megalomycteridae, a previously unrecognized family of deep-sea cetomimiform fishes based on two new genera from the North Atlantic. Stanford Ichthyol. Bull. 8(3): 194–206, figs. 1–5.

NICOL, J. A. C. 1967. The luminescence of fishes. Symp. Zool. Soc. Lond. 19: 27–55, 14 figs.

———. 1969. Bioluminescence. Pp. 355–394 *in* Hoar, S. and D. Randall, eds., Fish physiology, vol. 3. Reproduction and growth: bioluminescence, pigments, and poisons. Academic Press, New York, 485 pp.

NORMAN, J. R. 1957. A draft synopsis of the orders, families, and genera of Recent fishes and fish-like vertebrates. The British Museum (Natural History), London. 649 pp. [Copyrighted 1966.]

PARR, ALBERT E. 1933. Deepsea Berycomorphi and Percomorphi from the waters around the Bahama and Bermuda islands. Bull. Bingham Oceanogr. Collect. Yale Univ. 3(6): 1–51, figs. 1–22.

———. 1934. Report on experimental use of a triangular trawl for bathypelagic collecting, with an account of the fishes obtained and a revision of the family Cetomimidae. Bull. Bingham Oceanogr. Collect. Yale Univ. 4(6): 1–59, figs. 1–21.

PATTERSON, COLIN. 1969. The caudal skeleton in Mesozoic acanthopterygian fishes. Bull. Br. Mus. (Nat. Hist.), Geol. 17(2): 1–102, 28 figs.

RASS, T. S. (editor). 1971. The life of animals. Vol. 4, no. 1, Fishes [in Russian]. Izdatel'stvo Prosveshcheniye, Moscow. 655 pp., 54 pls.

ROBINS, C. RICHARD. 1966. Additional comments on the structure and relationships of the mirapinniform fish family Kasidoroidae. Bull. Mar. Sci. 16(4): 696–701, figs. 1–3.

———. 1974. *Review of* "Fishes of the western North Atlantic. No. 1, part six. Order Heteromi (Notacanthiformes), Suborder Cyprinodontoidei, Order Berycomorphi (Beryciformes), Order Xenoberyces (Stephanoberyciformes), Order Anacanthini (Gadiformes) in part Macrouridae." Copeia 1974(2): 574–576.

———, AND DONALD P. DE SYLVA. 1965. The Kasidoroidae, a new family of mirapinniform fishes from the western North Atlantic Ocean. Bull. Mar. Sci. 15(1): 189–201, figs. 1–2.

ROSEN, DONN ERIC. 1973. Interrelationships of higher euteleostean fishes. Zool. J. Linn. Soc., Suppl. 1, 53: 397–513.

———, AND COLIN PATTERSON. 1969. The structure and relationships of the paracanthopterygian fishes. Bull. Am. Mus. Nat. Hist. 141(3): 359–474, pls. 52–78, 78 figs.

SPRINGER, STEWART, AND HARVEY R. BULLIS, JR. 1956. Collections by the OREGON in the Gulf of Mexico. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 196. 134 pp.

THORP, C. H. 1969. A new species of mirapinniform fish (family Kasidoroidae) from the western Indian Ocean. J. Nat. Hist. 3(1): 61–70, 4 figs.

VINOGRADOV, M. E. 1970. Vertical distribution of the oceanic zooplankton. Tr. Inst. Okeanol., Akad. Nauk SSSR. [Translated from Russian by the Israel Program for Scientific Translation, Keter Press, Jerusalem. 339 pp.]

VOSS, GILBERT L., AND ROBERT F. SISSON. 1967. Squids: jet-powered torpedoes of the deep. Natl. Geogr. Mag. 131(3): 386–411, 29 figs.